

The Aging Raptor

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KEYWORDS

• Raptor • Bird of prey • Age • Geriatric

Birds of prey have been used in various manners by humans, worldwide, for centuries. Despite this fact, the information available in the literature on geriatric raptors is sparse, anecdotal, and written in various languages and journals that may not be easily accessible. Veterinarians beginning a career with raptors have a daunting task ahead of them. Becoming familiar with species commonly encountered, their natural history, husbandry requirements, dietary needs, and basic disease conditions is the foundation of raptor medicine. These fundamentals will allow the veterinarian to more correctly identify symptoms that may reflect geriatric conditions and aid in age determination of raptors on presentation. The goal of this article is to expose the reader to the numerous aspects that may affect raptor survival, longevity, and health. In addition, the most frequently seen geriatric disease conditions are reviewed.

RAPTORS AND THEIR USE BY HUMANS

Falconry

According to some experts, the origins of falconry date back to 4000 to 6000 BC in the steppes of Mongolia. Other historians have found records identifying birds of prey being used in Iran over 8,000 to 10,000 years ago. Falconry became well established in Asia and the Middle East by 2000 BC, and soon after migrated to Europe. Birds of prey were a status symbol and the sport of royalty from the sixth century through the Middle Ages. In the 1600s in England, the Laws of Ownership were used to allow citizens of various social rank to fly certain birds of prey. Popularity in Europe began to decrease in the 1800s because of the increased use of firearms, decline of the aristocracy, and land development for agriculture. Resurgence was not seen again until the 1920s and 1930s.

In North America, falconry dates back to the early 1500s, when the Aztecs used trained hawks. The first documentation of falconry in the United States was in New England in 1622. The first falconry association established in the United States was the Falconer's Association of North America in 1940, but it was disbanded during World War II. Since that time, the North American Falconry Association (NAFA) was formed in 1961 and currently has more than 2000 members.

As expected, medical conditions and treatments have been identified and used since the early days of falconry. Early writings of European falconers of the thirteenth

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to the nineteenth centuries describe many of the disease conditions encountered today.¹ Falconry husbandry techniques have historically been one of the primary modalities used to care for and treat birds of prey. Fortunately, advancement of veterinary care for falconry birds has resulted in falconers more frequently turning to veterinarians for care and treatment of their birds. Institutions such as the Abu Dhabi Research Hospital have led the way for specialized veterinary care for falconry birds.²

Zoologic Institutions

Displaying raptors is commonplace in most zoologic facilities exhibiting birds. Institutions not only exhibit birds of prey but also have demonstrations, interactive programs, and shows that allow the public to view these birds performing many of their natural behaviors. The combination of educating while entertaining is a powerful tool that is used by most institutions to raise awareness for target species. In addition, many zoos are involved in conservation efforts locally and internationally to increase public awareness and help secure sustainability of sensitive species through efforts ranging from fundraising to captive breeding. One unique aspect of raptors housed in captivity is the absence of environmental pressures, which results in increased life expectancy when compared with their wild counterparts. The overall increase in the number of zoos, birds housed at these institutions, and successful conservation projects has resulted in a greater need for veterinary care for these specialized birds.

Due to the increased longevity of raptors kept in zoologic collections, veterinarians have had the opportunity and ability to observe, document, diagnose, and treat various conditions, both common and uncommon. The advent of advanced diagnostic testing, including molecular techniques and diagnostic imaging, has also aided in the improvement of raptor medicine. Furthermore, development of new diagnostics and therapies has resulted in increased life expectancy of many individuals who in the past would have gone undiagnosed or untreated. The results of conservation efforts by zoologic facilities, biologists, and veterinarians can be seen with species such as the bald eagle, California condor, peregrine falcon, Aplomado falcon, and many others around the world.

Wildlife

Significant research and conservation efforts have been performed by scientists, biologists, ornithologists, naturalists, and veterinarians in the area of the natural history and medicine of wild raptors. Investigation into the natural history of these birds has expanded the basic knowledge of many species and has allowed a better understanding of many unfamiliar aspects of these birds, including migratory routes, hunting techniques, and reproduction. Molecular testing has been used to evaluate genetic diversity and identify gender prior to hatching. Naturalists are a key motivating and influential component to evaluation of wildlife. Events such as the Christmas Bird Count, Whooping Crane Festival, Florida Keys Raptor Migration Project, and others are prime examples of community involvement in the preservation and protection of wildlife. Whereas many of these events are casual, others are strictly scientific and are important indicators of the wild populations, and may provide the first indications of serious impacts and trends on wildlife.

The encroachment of human development into naive areas inhabited by raptors has resulted in an increased number of injuries and mortality. The increased impact on wildlife has motivated individuals and organizations to establish wildlife rescue and rehabilitation facilities to care for these birds. National and international organizations such as IWRC (International Wildlife Rehabilitation Counsel) and NWRA (National Wildlife Rehabilitators Association) have also been formed to collectively disseminate

knowledge with regard to rescuing, rehabilitating, and releasing birds as well as educating the public. Most large metropolitan cities have raptor rescue organizations that play a key role in rehabilitation. The information gathered from rehabilitation facilities and veterinarians has been an invaluable resource for expanding the practice of raptor medicine and surgery.

Divisions of Raptors

The distinction between falconry birds, zoo exhibit birds, and wildlife are identified to make the clinician aware that these divisions may alter the definition of what is considered a “geriatric” raptor. Even though there are morphologic characteristics in various raptor species that enable them to be identified as hatchlings, juveniles, sub-adults, and adults, determining the age of an adult raptor with an unknown history is difficult if not impossible.

Age Determination in Raptors

Identifying the correct age of raptors is fraught with endless variables that must be taken into consideration. Young raptors may be identified by behavioral and morphologic characteristics that employ both subjective and objective observations.^{3–9} Young raptors may be recognized over the first few years of life by their plumage (Figs. 1–6). Some raptor species maintain their juvenile plumage for 1 to 2 years, whereas other species, such as the bald eagle, may maintain their juvenile plumage for up to 4 to 5 years. Behavioral aspects may also indicate that an individual is young, even though it may have adult plumage. Juvenile birds often are presented to rehabilitation facilities due to traumatic injuries while hunting. Other individuals may be emaciated and weak due to their lack of hunting experience soon after fledging.

Adult raptors are significantly more difficult to age. Behavioral and morphologic characteristics are of little aid except to differentiate adults from the juveniles. The most helpful tool used to determine age of raptors is record keeping. Documentation by falconers, scientists, naturalists, and veterinarians is often the only way to determine their age. The use of radio telemetry, leg bands, microchips, and medical records have also been incorporated in studying these birds.^{10–12} Organizations such as Hawk Watch International are important contributors to increasing the knowledge base for raptor aging and longevity.



Fig. 1. Juvenile great horned owl (*Bubo virginianus*). (Courtesy of Tim Tristan, DVM.)



Fig. 2. Adult great horned owl (*Bubo virginianus*). (Courtesy of Tim Tristan, DVM.)

Aging raptors for all intensive purposes is an inexact science unless meticulous record keeping has been performed or is available. Therefore, identifying the geriatric raptor by the veterinarian requires a compilation of the information already stated in addition to the history, signalment, symptoms, and clinical signs.

Morbidity, Mortality, and Life Expectancy

One approach to recognizing geriatric raptors is identifying morbidity and mortality events and their frequency, impact, and effect on raptor populations. These variables have a direct correlation with the life expectancy of wild raptors. The most well-documented morbidity and mortality reports in the literature involve wild populations of birds of prey. Record life spans are listed in [Table 1](#).

Morbidity and mortality reports can be classified into 2 categories, human influence and environmental impact. Human influence affects birds of prey both directly and indirectly. The majority of mortality events in raptors are due to traumatic injuries.¹⁷⁻²³ Traumatic injuries may be the result of vehicular impact, collision with buildings, unspecified impact injuries, or gunshot wounds.^{17,21,22,24-28}

Indirect impacts by humans may also be seen in the form of toxicoses and land development for human use.²⁹ The most well-publicized toxins affecting birds of prey are dichlorodiphenyltrichloroethane (DDT) and lead. DDT resulted in a worldwide decrease in raptor populations. Since that time, DDT has been banned in most developed countries.³⁰ Lead has also been identified as having a significant effect on raptor



Fig. 3. Juvenile barn owls (*Tyto alba*). (Courtesy of Tim Tristan, DVM.)



Fig. 4. Adult barn owl (*Tyto alba*). (Courtesy of Kelly Shutt.)

populations. Lead exposure is generally due to ingestion of prey items containing lead shot, fishing sinkers, or high tissue-lead concentrations.^{31–33} The toxic side effects of lead have resulted in the ban of lead shot in North American wetlands and other places around the world. Non-lead alternatives such as steel, tungsten-nickel-iron, and bismuth-tin are now being used. There are numerous other toxins that are being investigated such as mercury, cadmium, chromium, diclofenac, famphur, carbofuran, fensulfothion, second-generation anticoagulant rodenticides, and numerous organophosphates/carbamates and organochlorines.^{34–44} Toxic compounds remain a serious threat to wild raptor populations.

Human development in previously unpopulated areas results in more encounters with wildlife, including raptors and their food sources. This encroachment often results in displacement of birds from their native hunting grounds and a decrease in their home range. Hakkarainen and colleagues⁴⁵ discovered that the annual survival of Tengmalm's owl was dependent on cover of old coniferous forests, and suggested that changes in habitat created by agriculture and forestry development may reduce adult survivability. Similar reports have prompted conservation efforts that also ensure preservation of habitat for raptor species. Electrocutation from power lines and trauma from collisions with wind power generators have also been identified as causes of



Fig. 5. Juvenile Eurasian eagle owl (*Bubo bubo*). (Courtesy of Tim Tristan, DVM.)



Fig. 6. Adult Eurasian eagle owl (*Bubo bubo*). (Courtesy of Patty Shoemaker Downtown Aquarium, Houston, TX.)

mortality in raptors (**Figs. 7** and **8**).^{17,21,24,25,46} The increase in the number of wind power generators over the coming years may have a significant impact in raptor populations.

Environmental factors may also affect the survivability and longevity of raptors. Natural disasters such as forest fires, hurricanes, tornados, and extreme weather events (ie, winter freezes), may significantly impact wild populations. Two extreme winters in Switzerland resulted in major population declines in barn owls.⁴⁷ Sarasola and colleagues⁴⁸ reported 113 Swainson's hawks and 45 birds of 11 other species that were found dead as a result of a single hailstorm in the Argentina Pampas. The event does not seem to be an isolated incident, as landowners have provided further evidence of past hailstorms with similar results.

Morbidity and mortality due to natural causes may be the result of predation, intra-specific conflict, orphaned young, starvation, infection, and metabolic, neoplastic, and degenerative diseases.⁴⁹ Heckel and colleagues⁵⁰ documented 3 cases of suspected fatal snakebite inflicted on 2 juvenile red-tailed hawks and one adult Cooper's hawk. Infectious causes of mortality may include bacterial, fungal, viral infections, and parasitism.^{51–53} The most recent viral infection affecting wild raptor populations in North America is the West Nile virus.^{54–57} Other viral infections that have been identified in raptors include Columbidae herpesvirus-1 in 2 Cooper's hawks and falcon adenovirus in an American kestrel (*Falco sparverius*).^{58,59} Further medical conditions are covered later in the article.

The age of some falconry birds may be known, often due to the fact that they were caught while in juvenile plumage or they were hatched by a falconer or aviculturist. Other birds used by falconers are of unknown age, and estimations must be made. In addition, many birds are used for hunting for only one season and subsequently released. Morbidity and mortality reports of falconry birds are sparse to nonexistent. Two reports in the literature revealed trauma as the primary cause of death in trained

Table 1
Longevity records of raptors (wild, falconry, and zoo birds)

Common Name	Scientific Name	Record Life Span	References
Turkey vulture	<i>Cathartes aura</i>	20 y	¹³
Eurasian black vulture	<i>Aegypius monachus</i>	39 y	¹³
White-backed vulture	<i>Gyps africanus</i>	19 y	¹³
Egyptian vulture	<i>Neophron percnopterus</i>	37 y	¹³
Black vulture	<i>Coragyps atratus</i>	25 y 6 mo	¹⁴
King vulture	<i>Sarcoramphus papa</i>	>40 y	Flanagan J, personal communication, 2009
Bearded vulture	<i>Gypaetus barbatus</i>	>40 y	¹⁵
Andean condor	<i>Vultur gryphus</i>	75 y	¹³
California condor	<i>Gymnogyps californianus</i>	45 y	¹³
Black-shouldered kite	<i>Elanus caeruleus</i>	6 y	¹³
Square-tailed kite	<i>Lophoictinia isura</i>	17 y	¹³
Black kite	<i>Milvus migrans</i>	24 y	¹³
White-tailed kite	<i>Elanus leucurus</i>	5 y 11 mo	¹⁴
Mississippi kite	<i>Ictinia mississippiensis</i>	11 y 2 mo	¹⁴
Snail kite	<i>Rostrhamus sociabilis</i>	17 y	¹³
Red kite	<i>Milvus milvus</i>	38 y	¹⁵
Swamp harrier	<i>Circus aeruginosus</i>	20 y	¹³
Pallid harrier	<i>Circus macrourus</i>	13 y	¹³
Montagu's harrier	<i>Circus pygargus</i>	16 y	¹³
Northern harrier	<i>Circus cyaneus</i>	16 y 5 mo	¹⁴
Sharp-shinned hawk	<i>Accipiter striatus</i>	19 y 11 mo	¹⁴
Cooper's hawk	<i>Accipiter cooperii</i>	20 y 4 mo	¹⁴
Northern goshawk	<i>Accipiter gentilis</i>	>28 y	¹⁴
Harris' hawk	<i>Parabuteo unicinctus</i>	25 y	¹³
Red-tailed hawk	<i>Buteo jamaicensis</i>	28 y 10 mo	¹⁴
Common buzzard	<i>Buteo Buteo</i>	24 y	¹⁴
Red-shouldered hawk	<i>Buteo lineatus</i>	19 y 11 mo	¹⁴
Swainson's hawk	<i>Buteo swainsonii</i>	24 y 1 mo	¹⁴
Broad-winged hawk	<i>Buteo platypterus</i>	18 y	¹³
Rough-legged hawk	<i>Buteo lagopus</i>	18 y	¹³
Ferruginous hawk	<i>Buteo regalis</i>	23 y 8 mo	¹⁴
Hawaiian hawk	<i>Buteo solitarius</i>	17 y	¹³
Common black hawk	<i>Buteogallus anthracinus</i>	13 y	¹³
Golden eagle	<i>Aquila chrysaetos</i>	>48 y	¹⁵
Bald eagle	<i>Haliaeetus leucocephalus</i>	31 y 4 mo	¹⁴
White-tailed sea eagle	<i>Haliaeetus albicilla</i>	95 y	¹⁵
Spanish imperial eagle	<i>Aquila adalberti</i>	44 y 5 mo	¹³
Wedge-tailed eagle	<i>Aquila audax</i>	40 y	¹³
Eastern imperial eagle	<i>Aquila heliaca</i>	56 y	¹³
Steppe eagle	<i>Aquila nipalensis</i>	41 y	¹³
Lesser spotted eagle	<i>Aquila pomarina</i>	26 y	¹³
Tawny eagle	<i>Aquila rapax</i>	40 y	¹³
Short-toed eagle	<i>Circaetus gallicus</i>	17 y	¹³

(continued on next page)

Table 1
(continued)

Common Name	Scientific Name	Record Life Span	References
Chilean eagle	<i>Geranoaetus melanoleucus</i>	42 y	13
Sea eagle	<i>Gypohierax angolensis</i>	27 y	13
Harpy eagle	<i>Harpia harpyja</i>	16 y	13
New Guinea eagle	<i>Harpyopsis novaeguineae</i>	30 y	13
Bonelli's eagle	<i>Hieraetus fasciatus</i>	20 y	13
Little eagle	<i>Hieraetus morphnoides</i>	10 y	13
Philippine eagle	<i>Pithecophaga jefferyi</i>	41 y	13
Eurasian eagle-owl	<i>Bubo bubo</i>	68 y	13
Saker falcon	<i>Falco cherrug</i>	29 y	15
Brown falcon	<i>Falco berigora</i>	16 y	13
Eleonora's falcon	<i>Falco eleonora</i>	11 y	13
Red-footed falcon	<i>Falco vespertinus</i>	13 y	13
Gyrfalcon	<i>Falco rusticolus</i>	13 y 6 mo	14
Mauritius kestrel	<i>Falco punctatus</i>	10 y 10 d	16
Eurasian kestrel	<i>Falco tinnunculus</i>	23 y	13
American kestrel	<i>Falco sparverius</i>	17 y	13
Lesser kestrel	<i>Falco naumanni</i>	10 y	13
Prairie falcon	<i>Falco mexicanus</i>	17 y 3 mo	14
Peregrine falcon	<i>Falco peregrinus</i>	25 y	13
Merlin	<i>Falco columbarius</i>	12 y	15
Aplomado falcon	<i>Falco femoralis</i>	12 y	13
Crested caracara	<i>Caracara cheriway</i>	25 y 8 mo	13
Southern caracara	<i>Caracara plancus</i>	37 y 6 mo	13
Osprey	<i>Pandion haliaetus</i>	26 y 2 mo	14
Bateleur	<i>Terathopius ecaudatus</i>	>55 y	15
Barn owl	<i>Tyto alba</i>	28 y	Flanagan J, personal communication, 2009
Long-eared owl	<i>Asio otus</i>	27 y	13
Short-eared owl	<i>Asio flammeus</i>	21 y 5 mo	14
Barred owl	<i>Strix varia</i>	18 y 2 mo	14
Spotted owl	<i>Strix occidentalis</i>	21 y	14
Great gray owl	<i>Strix nebulosa</i>	12 y 9 mo	14
Boreal owl	<i>Aegolius funereus</i>	15 y	13
Northern saw-whet owl	<i>Aegolius acadicus</i>	17 y	13
Eastern screech owl	<i>Otus asio</i>	20 y	14
Western screech owl	<i>Otus kennicottii</i>	19 y	13
Flammulated owl	<i>Otus flammeolus</i>	7 y	14
Great horned owl	<i>Bubo virginianus</i>	29 y	14
Snowy owl	<i>Nyctea scandiaca</i>	28 y	13
Burrowing owl	<i>Athene cunicularis</i>	11 y	13
Little owl	<i>Athene noctua</i>	9 y	13
Eurasian pygmy owl	<i>Glaucidium passerinum</i>	6 y	13
Eurasian scops-owl	<i>Otus scops</i>	6 y	13
Elf owl	<i>Micrathene whitneyi</i>	14 y	13



Fig. 7. Birds of prey, such as this osprey (*Pandion haliaetus*), are frequently seen perched on power lines while hunting for prey. (Courtesy of Tim Tristan, DVM.)

raptors.^{60,61} One report involved the British Falconry Club (BFC) where 197 trained raptors were followed over a 6-year period and 76 (38.5%) deaths were recorded. Twenty-four (12.1%) birds died as a result of trauma. Anecdotal reports also support that a common cause of raptor mortality is trauma, whereas others report infectious disease, ophthalmic disease, and organ failure as being more common.

Probably the best documentation of geriatric raptors is by zoologic institutions and educational facilities. These birds may have been acquired through breeding programs, conservation projects, and wildlife rehabilitation centers. Many birds used for educational programs or exhibits originate from rehabilitation facilities where it has been determined the animal is unfit for release. Other projects, such as the California Condor Conservation project, are an integral part of zoo and wildlife conservation efforts in expanding the knowledge base of the many aspects of their care. Rehabilitation facilities frequently use nonreleasable individuals as animal ambassadors to educate the public on the pressures inflicted by humans on birds of prey.



Fig. 8. A red tailed hawk (*Buteo jamaicensis*) found near an electrical transformer had severe burns on the talons leading to a diagnosis of electrocution. (Courtesy of Tim Tristan, DVM.)

When compared with other methods of evaluating morbidity and mortality reports of geriatric birds, zoo and educational birds are the most significant resource available.

DISEASE CONDITIONS

Musculoskeletal Diseases (Degenerative Joint Disease and Osteoarthritis)

Musculoskeletal changes due to age are most often related to osteoarthritis and degenerative joint diseases. Although these terms may be interchanged frequently, they are distinct. Osteoarthritis is a pathologic change of a diarthrodial synovial articulation, including the deterioration of articular cartilage, osteophyte formation, bone remodeling, soft tissue changes, and low-grade nonpurulent inflammation. Degenerative joint disease, in comparison, is a general term used to describe any degenerative change in synovial cartilaginous or fibrous articulation in the skeleton. The increase in life expectancy in domestic animals and the associated geriatric conditions such as arthritis has resulted in development of improved diagnostics and treatment modalities for these patients. The information gained from domestic species has allowed for a better understanding of these conditions in avian species, although much work remains to be done.

Few reports in the literature discuss osteoarthritis or degenerative joint diseases in birds as it relates to age. Disease conditions such as gout, bacterial and fungal osteomyelitis, and trauma-related injuries comprise the majority of bone- and joint-related reports. Rothschild and Panza⁶² examined museum specimens of 2243 free-ranging hawks and determined that 3% had osteoarthritis, all localized to the ankle. In addition, there was not enough evidence to correlate age with the development of osteoarthritis. Despite this fact, geriatric birds seen by veterinarians frequently present with bone- and joint-related disease conditions. Cooper⁶³ describes a condition seen in older raptors resembling rheumatoid arthritis in which one or both legs become stiff and the bird is unable to stand. The patients' symptoms may resolve but often reoccur with intermittent signs of collapse. A cardiovascular component to the condition has been hypothesized. Many raptors examined by veterinarians have preexisting medical conditions that predispose them to arthritis. Previous traumatic injuries are the most common cause of development of arthritis in patients seen by the author. Wing injuries involving the humerus, radius, ulna, and carpus have all been associated with development of osteoarthritis and degenerative joint disease. Osteoarthritis also occurs in the long bones of the legs, but is less frequently observed in comparison with the wing. Fractures that are near the joints appear to result in the most severe cases of degenerative joint disease and osteoarthritis. The contradiction in reports of osteoarthritis in wild caught birds as opposed to that described anecdotally by veterinarians may be due to the status of the birds (ie, wild vs captive). Wild birds that are presented to rehabilitation facilities rarely have chronic bone or joint disease. The limited number of raptors presented to rehabilitation facilities with chronic joint injuries is likely due to their decreased ability to effectively hunt and sustain their caloric needs in the wild.

Falconry birds with osteoarthritis and degenerative joint disease of the shoulder, elbow, carpus, stifle, and tarsus are seen occasionally. The most frequent diagnosis of arthritis in falconry birds made by the author is related to the elbow and tarsus. Historical reports of trauma and bumblefoot related injuries seem to be predisposing factors affecting the development of osteoarthritis in these 2 areas. Raptors in zoologic collections seen with osteoarthritis and degenerative joint disease are becoming more frequent due to the increased longevity and extensive veterinary care these birds receive. In the author's experience, arthritis in these individuals is most frequently located in the stifle and tarsus; this is likely due to lack of conditioning or obesity.

Arthritis is usually suspected due to clinical signs. Arthritis related to the legs may result in shifting leg lameness, development of bumblefoot, joint and leg swelling, edema, uncoordinated movements, curling of the foot, and decreased range of motion. Arthritis related to the wings may also result in many of the same conditions, including wing drooping or inability to place the wing in full extension or flexion. Raptors that are part of a show or program will frequently exhibit behavioral cues that indicate there may be a problem. Decreased activity level, inability to capture and hold prey, failure to meet criteria for specific behaviors, and inappetence may all be observed by falconers, keepers, and trainers as well as veterinarians.

A thorough physical examination should begin with visual examination of the patient before the “hands on” examination. Most birds of prey, like many other avian species, will appear normal on first glance. Given time, once the birds become more comfortable with their surroundings and presence of onlookers, clinical signs may be noted. Only when the bird has been fully evaluated visually should it be captured for the physical examination. Many veterinarians perform a physical examination and then perform a more in-depth orthopedic examination to evaluate bone and joint conditions. The orthopedic examination is conducted on the legs and wings, starting distally and working toward the most proximal joint. Each joint is manipulated in flexion and extension to evaluate for crepitus, decreased range of motion, or other abnormalities. Care must be taken by the examiner when evaluating the feet as injury may occur if taloned by the patient. On completion of the physical examination, diagnostics may be pursued.

The primary diagnostic used to evaluate for osteoarthritis and degenerative joint disease is radiography. The advent of digital radiography has revolutionized diagnostic imaging for evaluating birds, including raptors. Ultrasound, computed tomography, and magnetic resonance imaging have also been used to further evaluate patients. Once the region of arthritis has been identified, a thorough diagnostic workup should be performed to identify the possible cause. Infectious, inflammatory, traumatic, neoplastic, nutritional, metabolic, and other differentials should be excluded before a final diagnosis of a degenerative joint or bone condition is definitively diagnosed.

Treatment of osteoarthritis should be addressed using a multimodal approach. First, identification of the arthritic location and the classification of the joint or bone should be performed. The classification of the joint (ie, fibrous, cartilaginous, synovial) may dictate which treatments may be most advantageous for the patient. In addition, husbandry conditions may need to be modified to improve the outcome.

Husbandry changes may include perch selection, exhibit location, activities performed, and environmental exposure. Obesity may complicate osteoarthritis and exacerbate the condition. For this reason, a raptor's weight should be monitored frequently, if not daily, to allow adjustments when needed. Weight management not only decreases the load the joints must carry but also prevents other conditions such as hepatic lipodosis. Osteoarthritis in the legs and feet frequently causes redistribution of weight onto the less affected foot, and may result in bumblefoot. Multiple perches of various sizes with appropriate cover (ie, artificial turf) should be used to aid in prevention of foot lesions caused by inappropriate weight distribution (**Fig. 9**). Birds on exhibit may select perches that are inappropriate for their needs to avoid close association with the public or staff. Thought should be given to the types of materials being used and the location in which they are being placed. Individuals that fly in shows or hunt may have to decrease the frequency with which they perform these tasks to prevent further damage or more serious life-threatening injuries. Removal from shows or hunting should be done in a gradual manner to prevent



Fig. 9. Osteoarthritis is seen more frequently in birds of prey such as this Southern Caracara (*Caracara plancus*) due to their increased longevity in captivity. Visualizing subtle clinical signs requires visual observation of the patient before restraint and “hands on” exam. (Courtesy of Tim Tristan, DVM.)

disease conditions such as avascular necrosis of the third digit, as seen in some raptors in the Middle East after the hunting season.⁶⁴ These determinations are made on a case by case basis and criteria for these decisions depend on the severity of the arthritis, other disease conditions, and experience of the falconer, keepers, or trainers. The stress of performing or being on exhibit for extended periods of time are factors that may be manipulated for some geriatric raptors to improve their well-being.

Pharmaceutical therapy is the most common and beneficial tool used by veterinarians to treat osteoarthritis. Multiple drugs are being used, with marked success, in many domestic and avian species. Nonsteroidal anti-inflammatory drugs (NSAIDs) are probably the most frequently used drugs, prescribed for their anti-inflammatory and analgesic properties in birds.^{65–71} Unfortunately, limited pharmacokinetic data exist for their use in avian species. In domestic species that have been studied more extensively, patients are monitored for side effects related to liver function, renal function, and gastrointestinal erosions. In these species, a standard hematology and chemistry profile is performed before initiating therapy, and periodically thereafter. The same protocol is recommended in birds before starting NSAID therapy. If renal, hepatic, or gastrointestinal conditions are identified before starting NSAIDs, consideration must be given to the benefit versus risk. Many of these drugs (aspirin, ketoprofen, ibuprofen, flunixin meglumine, phenylbutazone) have fallen out of favor due to toxic side effects seen in birds, including renal failure, prolonged clotting times, and gastrointestinal ulceration.⁷² At present, the 2 most frequently used NSAIDs used in avian species are carprofen (Rimadyl) and meloxicam (Metacam). Both drugs have shown adequate analgesia in osteoarthritis as well as other painful conditions, and minimal side effects compared with their predecessors. Other NSAIDs such as

celecoxib are being used in psittacines, but their use in raptors has not yet been evaluated.⁷³

Opioids, although used commonly in domestic animals such as dogs and cats, have had limited use in avian species. Part of the reason is a lack of published data on opiate receptors and their distribution and function in avian species. There is increasing debate over the roles of κ , μ , and δ receptors and their response to specific opiates. Morphine, butorphanol, buprenorphine, fentanyl, and codeine have all been investigated for their use in birds, but few have been evaluated for their use in raptors.^{72,74–85} Opioids are most often used for presurgical administration in birds, but are rarely used long term in any species because of potential side effects including cardiac and respiratory depression, sedation, euphoria, inappetence, and constipation.

Tramadol is used for pain control in several different species due to its affinity for the μ receptor, yet it is not classified as an opioid. Tramadol is thought to provide analgesia by acting on opioid, serotonin, and norepinephrine pathways.⁸⁶ Tramadol is frequently used for chronic pain in other species, and is thought to work synergistically with NSAIDs. A study performed by Souza and colleagues⁸⁷ evaluated 6 bald eagles administered tramadol intravenously and orally to determine plasma concentrations over time.⁸⁷ The author has used tramadol, 1 to 4 mg/kg, in raptors and psittacines, with promising results. In 2 cases of osteoarthritis in red-tailed hawks (*Buteo jamaicensis*) older than 20 years, positive results were noted by trainers and staff, with no evidence of side effects. Further investigations need to be performed to evaluate the analgesic properties of tramadol in raptors.

Nutraceuticals are often used as part of the treatment protocol for many species with osteoarthritis. Products such as Cosequin, Adequan, and others contain glucosamine, chondroitin sulfate, and Omega-3 fatty acids. These products are intended to help rebuild the cartilage that has broken down over time and repair damage that has been done. Although there are few reports in the literature, the author has seen positive results with Cosequin administered orally to several avian species including raptors.⁸⁸

Tricyclic antidepressants including amitriptyline, clomipramine, and imipramine provide relief to individuals with chronic neuropathic pain, and are thought to alter the actions of serotonin and norepinephrine both centrally and peripherally.⁸⁹ The majority of the reports related to birds in the literature are in reference to feather picking and self-mutilating psittacines. The use of tricyclic antidepressants in raptors remains to be seen. Conditions such as self-mutilation in Harris hawks may also benefit from this class of drug.^{90,91}

The anticonvulsant gabapentin is clinically effective in relieving some types of chronic pain in people, and has been used in dogs and cats, yet the mechanism of action is unclear. Side effects seen in cats include ataxia and sedation. One report of gabapentin use in birds reported a dose of 10 mg/kg given twice a day by mouth in a little corella.⁹² A second case of a Senegal parrot (*Poicephalus senegalus*) with leg twitching and foot mutilation caused by neuralgia reported the use of gabapentin at a dose of 3 mg/kg every 24 hours by mouth to be effective.⁹³ To the author's knowledge there are no reports of gabapentin use in raptors.

Physical therapy, including passive range of motion and techniques used by falconers for conditioning, can aid in treatment of osteoarthritis and result in an improved quality of life. Rehabilitation and physical therapy are discussed in a later section.

Neoplasia

Neoplastic disease conditions have been reported in the literature with increased frequency as the life span of birds has steadily increased. Neoplastic conditions

reported in raptors are listed in **Table 2**. Diagnosis of neoplasia is dependent on history and physical examination findings, but may also require advanced diagnostic techniques. Radiography, computed tomography, ultrasonography, cytology, and histopathology may each be crucial in the definitive diagnosis of neoplasia.

Treatment of neoplastic disease conditions depends on the type, location, expected response to therapy, and condition of the patient. Once these variables have been determined, a palliative, moderate, or aggressive course of therapy should be chosen. Therapy may include surgical excision, cryotherapy, chemotherapy, photodynamic therapy, radiation therapy, or any combination of these. Most neoplastic tumors in raptors reported in the literature have been surgically excised.⁹⁴ Chemotherapy agents including prednisolone, doxorubicin, cisplatin, carboplatin, chlorambucil, cyclophosphamide, vincristine, and α -interferon have all been used in the treatment of specific neoplastic conditions in other orders of birds, primarily psittacines.^{98–105} Radiation therapy was performed in a golden eagle (*Aquila chrysaetos*) with squamous cell carcinoma.^{106–108} Although neoplastic conditions may occur in raptors at any age, they primarily occur in older geriatric raptors.

Cardiovascular Disease

Cardiovascular disease in avian species has recently received more attention in the veterinary literature, yet the information available is still limited. In addition, most reports of cardiovascular disease involve psittacines, and those in raptors are primarily diagnosed post mortem. Finding cardiovascular disease on postmortem examination also leaves the question of whether the cardiovascular disease was the primary cause of death, a contributory cause of death, or an incidental finding. A combination of history, physical examination, clinical signs, and diagnostic testing may need to be used to formulate a diagnosis and illuminate the affects associated with cardiovascular disease in raptors.

The physical examination should begin with a visual assessment of the bird in its enclosure or mew, followed by examination on the fist, before the “hands-on” physical examination is performed. Clinical signs of cardiovascular disease may vary, but include exercise intolerance, dyspnea, ascites, weakness, neurologic signs, edema of the head and feet, and sudden death. The physical examination should include a complete evaluation of the patient including auscultation of the heart and lungs. Auscultation may reveal arrhythmias, murmurs, and pulmonary congestion, but may be difficult to assess due to the elevated heart rate compared with other species. The veterinarian must be cognizant of the response of the bird to handling, and be prepared to terminate the examination if the patient’s condition declines. Dyspnea, tachypnea, collapse, syncope, or seizure activity may all warrant termination of the examination. Special attention should be paid to the extremities (especially the tarsus and digits), as swelling is commonly seen in older raptors with cardiovascular disease.

Diagnostic testing may include hematology, biochemistry, radiography, echocardiography, endoscopy, electrocardiography, and blood pressure measurement.

Radiographs allow visualization of the heart, aorta, brachiocephalic trunk, and pulmonary vessels. Abnormalities may be seen with the size and shape of the heart, increased radiodensity of large vessels (ie, arteriosclerosis), and enlargement of vessels such as the aorta. Changes in the lungs, liver, and air sacs, secondary to heart disease, may also be noticed, including hepatomegaly, increased radiodensity of the lungs, pleural effusion, and ascites. Measurement of heart length is difficult to assess due to the superimposition of the apex of the heart over the liver. Recommendations for psittacines have been made, which involve measurement of the heart silhouette on ventrodorsal radiographs at its maximum width compared with the width of the thorax

Table 2
Neoplasia reports in birds of prey

Tumor	Number of Cases in the Literature	Species	Average Age	Age Range	References
Fibrosarcoma	17	Multiple species	6.9 y	6 mo to 12 y	⁹⁴
Myxofibroma	1	Cape griffon vulture	17 y	17 y	⁹⁴
Fibroma	1	European kestrel	Unknown	Unknown	⁹⁴
Histiocytic carcinoma	2	Great horned owl	<1 y and one adult	<1 y and one adult	⁹⁴
Lipoma	4	Multiple species	13 y	9–16 y	⁹⁴
Osteosarcoma	2	Hybrid falcon, Eurasian buzzard	Unknown	Unknown to adult	⁹⁴
Osteoma/ Chondroma	4	Multiple species	13 y	6–15 y	⁹⁴
Rhabdomyosarcoma	1	Lappet-faced vulture	19 y	19 y	⁹⁴
Leiomyoma	2	Golden eagle, peregrine falcon	17 y	17 y	^{94,95}
Mixed cell tumor	1	Seychelles kestrel	30 d	30 d	⁹⁴
Adenocarcinoma	16	Multiple species	21.4 y	6–26 y	⁹⁴
Adenoma	1	Multiple species	13.5 y	7–20 y	⁹⁴
Bile duct carcinoma	3	Multiple species	23 y	13–33 y	⁹⁴
Cholangiocarcinoma	1	Red-tailed hawk	Unknown	Unknown	⁹⁶
Cystadenocarcinoma	1	Peregrine falcon	Unknown	Unknown	⁹⁵
Cholangiocellular carcinoma and renal adenocarcinoma	1	Golden eagle	Unknown	Unknown	⁹⁷
Carcinoma	5	Multiple species	8 y	18 mo to 2 y	⁹⁴
Thyroid follicular cystadenoma	1	Crested caracara	7 y	7 y	⁹⁴
Thyroid cystic fibroadenoma	1	Black-chested Buzzard eagle	>27 y	>27 y	⁹⁴
Adrenal cortical adenoma	1	Long-crested eagle	20 y	20 y	⁹⁴
Squamous cell carcinoma	13	Multiple species	8.7 y	4–15 y	⁹⁴
Epidermoid carcinoma	2	Red-tailed hawk	Unknown	Unknown	⁹⁴
Papilloma	6	Multiple species	4 y	6 mo to 9 y	⁹⁴
Hemangioma	1	Peregrine falcon	15 y	15 y	⁹⁴
Mast cell tumor	3	Multiple owl species	Unknown	Unknown	⁹⁴
Melanoma	3	Multiple owl species	20 y	10–31 y	⁹⁴
Astrocytoma	1	Great horned owl			⁹⁴

(continued on next page)

Table 2
(continued)

Tumor	Number of Cases in the Literature	Species	Average Age	Age Range	References
Malignant lymphoma	4	Multiple species	12 y	>8–18 y	⁹⁴
Malignant thymoma	1	Saker falcon	12 y	12 y	⁹⁴
Lymphoid leukosis	4	Multiple species	2.5 y	3 mo to 3 y	⁹⁴
Erythroblastosis	1	Gyr Falcon	Unknown	Unknown	⁹⁴
Lymphosarcoma	3	Multiple species	22 y	22 y	⁹⁴
Teratoma	1	Eurasian buzzard	10 y	10 y	⁹⁴
Xanthoma	3	Multiple species	18 y	2 to >40 y	⁹⁴
Mesothelioma	2	Ferruginous hawk	4.5 y	4–5 y	⁹⁴

at the same level.¹⁰⁹ In medium-sized psittacines (200–500 g) the width of the cardiac silhouette should be 51% to 61% of the thoracic width. Hanley and colleagues¹¹⁰ determined that the width of the cardiac silhouette in the Canadian goose was 47% to 57% of the thoracic width, so species variation seems to exist. Radiographic measurements in raptors remain to be evaluated.

Echocardiography allows further evaluation of the heart structure, function, and kinetics. Visualization of the heart is achieved by a ventromedian approach with the patient in a slightly upright position. On occasion feathers must be removed to allow better contact between the probe and the patient. Echocardiography may reveal decreased contractility, increased thickness of heart chambers and vessels, pericardial effusion, and valvular dysfunction. Color flow Doppler greatly improves diagnostic capabilities regarding evaluation of the heart valves. Reference values have been established for psittacines, pigeons, and raptors.¹¹¹ Reference values of echocardiograms for raptors are listed in **Table 3**.

Electrocardiography (ECG) may be used for the detection of arrhythmias, conduction disorders, metabolic disorders, and ventricular enlargement. ECG may also be used along with echocardiography to allow measurement at definitive stages of the heart cycle. ECG reference values have been evaluated for multiple Falconiformes and Strigiformes in a study by Burtnick and Degernes.¹¹² Reference values of ECG for raptors are listed in **Table 4**.

Endoscopy is another diagnostic tool used for direct visualization of the heart, great vessels, and cardiovascular associated structures.

Diagnostic evaluation should be used to investigate for primary cardiovascular disease as well as conditions that may result in secondary cardiac disease such as gout and septicemia. Reports of cardiovascular disease in raptors include atherosclerosis, ischemic heart disease, vegetative endocarditis, aortic ruptures, toxemia, myocarditis, pericardial effusion, dilated cardiomyopathy, and neoplasia.

Atherosclerosis has been frequently described in birds of prey. Keymer¹¹³ analyzed over 125 birds of prey and found that 10% of Falconiformes and more than 15% of Strigiformes were afflicted with this form of heart disease. More than 85% of the Falconiformes were older than 10 years and all but one of the Strigiformes was older than 12 years. Finlayson¹¹⁴ noted that the highest incidence of lipid-containing plaques occurred in Falconiformes, approaching 54% in comparison with 6 other Orders of birds in which incidence was between 20% and 30%. Lesions frequently seen with atherosclerosis primarily affect the brachiocephalic trunk and abdominal aorta, with

Table 3

Electrocardiogram (Lead II) heart rate and duration of ECG intervals under anesthesia with ketamine and xylazine

Common Name	Scientific Name	n	Heart Rate (Beats/min)	P (s)	PR (s)	QRS (s)	QT (s)
Bald eagle	<i>Haliaeetus leucocephalus</i>	20	82 (50–160)	0.041 (0.03–0.06)	0.091 (0.07–0.11)	0.029 (0.02–0.04)	0.135 (0.11–0.165)
Great horned owl	<i>Bubo virginianus</i>	8	111 (100–130)	0.037 (0.03–0.05)	0.086 (0.07–0.1)	0.025 (0.02–0.03)	0.149 (0.125–0.165)
Red-tailed hawk	<i>Buteo jamaicensis</i>	11	122 (80–220)	0.032 (0.02–0.035)	0.071 (0.05–0.09)	0.025 (0.02–0.03)	0.116 (0.08–0.165)
American kestrel	<i>Falco sparverius</i>	8	158 (120–200)	0.03 (0.03–0.035)	0.059 (0.05–0.065)	0.021 (0.015–0.025)	0.099 (0.085–0.12)
Golden eagle	<i>Aquila chrysaetos</i>	2	100 (100)	0.043 (0.04–0.045)	0.09 (0.085–0.095)	0.025 (0.025)	0.142 (0.135–0.15)
Peregrine falcon	<i>Falco peregrinus</i>	2	95 (90–100)	0.035 (0.035)	0.072 (0.07–0.075)	0.025 (0.025)	0.135 (0.125–0.145)
Barred owl	<i>Strix varia</i>	2	120 (100–140)	0.055 (0.05–0.06)	0.105 (0.1–0.11)	0.027 (0.025–0.03)	0.145 (0.14–0.15)
Saw-whet owl	<i>Aegolius acadicus</i>	2	240 (200–280)	0.018 (0.01–0.025)	0.055 (0.05–0.06)	0.02 (0.02)	0.102 (0.085–0.12)
Cooper's hawk	<i>Accipiter cooperii</i>	2	160 (140–180)	0.027 (0.025–0.03)	0.062 (0.055–0.07)	0.025 (0.025)	0.098 (0.095–0.1)
Sharp-shinned hawk	<i>Accipiter striatus</i>	2	220 (200–240)	0.03 (0.03)	0.06 (0.055–0.065)	0.02 (0.02)	0.11 (0.09–0.13)

Data from Burtinck NL, Degernes LA. Electrocardiography on fifty-nine anesthetized convalescing raptors. In: Redig PT, Cooper JE, Remple JD, et al, editors. Raptor biomedicine. Minneapolis: University of Minnesota Press; 1993. p. 111–21.

Table 4 Echocardiographic parameters in raptors		
Parameter	Diurnal Raptors	Diurnal Raptors
	Horizontal View	Vertical View
Body mass	720 ± 197	
Left ventricle		
Length systole (mm)	14.7 ± 2.0 male	17.7 ± 1.2 male
	14.7 ± 4.5 female	18.2 ± 4.7 female
Length diastole (mm)	16.5 ± 1.8 male	19.3 ± 1.6 male
	16.3 ± 4.5 female	20.1 ± 5.2 female
Width systole (mm)	6.1 ± 0.8 male	6.6 ± 0.9 male
	6.8 ± 1.7 female	7.7 ± 1.8 female
Width diastole (mm)	7.4 ± 1.0 male	7.5 ± 1.0 male
	8.3 ± 1.8 female	8.9 ± 2.1 female
Width fractional shortening (%)	unknown	unknown
Right ventricle		
Length systole (mm)	12.6 ± 1.9 male	
	13.0 ± 4.6 female	
Length diastole (mm)	13.8 ± 1.8 male	
	14.2 ± 4.2 female	
Width systole (mm)	2.1 ± 0.5 male	
	2.2 ± 0.8 female	
Width diastole (mm)	2.5 ± 0.7 male	
	2.5 ± 1.1 female	
Width fractional shortening (mm)	Unknown	
Interventricular septum		
Thickness systole (mm)	1.8 ± 0.4 male	
	2.0 ± 0.8 female	
Thickness diastole (mm)	1.9 ± 0.4 male	
	2.0 ± 0.7 female	
Aorta diameter diastole	2.7 ± 0.4 male	
	2.9 ± 0.4 female	

Data from Pees M, Krautwald-Jughanns ME. Cardiovascular physiology and disease of pet birds. *Vet Clin North Am Exot Anim Prac* 2009;12(1):81–97; Boskovic M, Krautwald-Junghanns ME, Failing K, et al. Möglichkeiten und Grenzen echokardiographischer Untersuchungen bei Tag- und Nachtgreifvögeln (Accipitriformes, Falconiformes, Strigiformes). *Tierarztl Prax* 1995;27:334–41.

similar lesions occurring in the subclavian, carotid, and femoral arteries. Gross necropsy may reveal degenerative changes and decrease in the lumen of the arterial wall by deposits of collagen, cholesterol, or calcium, but in some cases gross post-mortem examination may be unremarkable.¹¹⁵ Obesity and lack of exercise seem to be predisposing factors.

Infectious causes of heart disease are primarily the result of bacterial infections but may also be caused by fungi and parasites resulting in endocarditis, myocarditis, and pericarditis. Vegetative endocarditis has been reported as a result of bumblefoot caused by frostbite in various species of birds, including raptors.¹¹⁶ Other infectious causes include salpingitis, nephritis, and hepatitis. Myocarditis may be the result of infections with bacteria, fungi, viruses, and parasites. The protozoan parasite *Sarcocystis* spp has been reported in European sparrowhawks.⁷² In addition,

histopathological changes consistent with myocarditis were seen in 23 of 38 raptors diagnosed with West Nile virus in a report by Saito and colleagues in 2007.⁵⁵

Metabolic conditions such as gout may also affect cardiac function. Renal and hepatic tissues are frequently affected by visceral gout. Other conditions such as dilated cardiomyopathy and degenerative cardiac disease have been seen in bearded vultures and bald eagles with lead toxicity, respectively.⁷²

The limited cases of cardiovascular disease diagnosed antemortem has resulted in few reports of drug use for these disease conditions in raptors. The author has used enalapril on a red-tailed hawk (*Buteo jamaicensis*) and a golden eagle (*Aquila chrysaetos*) at a dose of 0.5 to 1.0 mg/kg every 24 hours by mouth, with no ill effects. Treatment of cardiovascular disease in raptors is an area where much work is still needed.

Organ Failure

Hepatic disease and renal disease are frequently identified disease conditions that affect older raptors, yet there are few reports in the literature.¹¹⁷ Hepatic and renal disease may be the result of several different origins including infectious, inflammatory, degenerative, metabolic, toxic, and neoplastic conditions. Hepatic diseases commonly include hepatic lipidosis, amyloidosis, mycobacteriosis, viral disease, and toxin accumulation. Renal diseases include amyloidosis, neoplasia, gout, viral disease, and toxin accumulation.

Ocular Disease

Falconers, zoologic institutions, and educational facilities frequently present raptors to veterinarians with ophthalmic disease associated with old age. Most forms of ocular disease in raptors are the result of traumatic injuries, many of which predispose raptors to chronic ocular conditions such as cataracts.^{118–121} Early detection, diagnosis, and treatment afford the patient the best chance for a favorable outcome.

History is a vital part of the information required when presented with a bird with an ocular condition. Although many traumatic injuries may occur while hunting or during handling by trainers or staff, it may also occur when the bird is on exhibit or in its mew. In these instances, the exact cause of the injury may not be known and the clinical signs may be the first indication of a problem. Clinical signs may consist of a closed eye, ocular discharge, blepharitis, hyphema, hypopyon, lens luxation, inability to close the eye, and anisocoria. Conditions such as iris discoloration due to chronic inflammation, cataract formation, and blindness may be seen with chronic disease.

Visual examination of the patient should be performed, as stated earlier, before a physical examination is performed. Birds that are not trained to come to the glove may initially need to be examined from a distance. If this occurs, binoculars may be used for initial evaluation of the patient without direct or close contact with the bird. Further, “hands-on” examination of the patient may require the use of an ophthalmoscope, fluorescein dye, a Schirmer tear test (STT), tonometry, slit-lamp biomicroscopy, and indirect ophthalmoscopy. Fluorescein staining is a quick, inexpensive technique that is frequently used for diagnosis of corneal defects from penetrating wounds, toxin exposure, and other corneal injuries.¹²² Korbel and Leitenstrofer¹²³ evaluated the use of a modified STT strip in normal birds of prey and identified reference ranges for Falconiformes and Strigiformes. Reference values for STT in raptors are listed in [Table 5](#). Marked decreases in the STT ranges were noted in Strigiformes, likely due to their small or absent orbital lacrimal gland. A wide reference range was reported and recommendations were made to assess birds based on their age, gender, and species differences. Further evaluation of the STT has been evaluated in screech owls and tawny owls.^{124,125} Tonometry can also be used for evaluation

Table 5
Lacrimal function of normal eyes measured using a modified Schirmer tear test (STT)

Common Name	Scientific Name	Strip (mm)	No. of Birds	No. of Eyes	STT with Topical Anesthesia (mm/min)	STT without Topical Anesthesia (mm/min)	STT with General Anesthesia (mm/min)
Common kestrel	<i>Falco tinnunculus</i>	5	15	30	4.07 ± 2.7	1.96 ± 1.7	2.34 ± 1.5
<i>Falco</i> spp	<i>Falco</i> spp	5	12	24	14.44 ± 7.2	4.17 ± 3.1	8.26 ± 4.6
Common buzzard	<i>Buteo buteo</i>	5	12	24	11.5 ± 5.4	5.9 ± 3.1	6.81 ± 3.8
Sparrow hawk	<i>Accipiter nisus</i>	5	4	8	10.63 ± 4	3.6 ± 1.7	
Strigiformes	Strigiformes	2	6	10	2.7 ± 1.4	1.25 ± 0.6	
Tawny owls	<i>Strix aluco</i>	2	Unknown	Unknown	3.2 ± 0.4 ^a		
Screech owls	<i>Megascops asio</i>	Unknown	21	21	2.0 with a range of 2–6		

^a It is unknown whether topical or general anesthesia was used in the birds in these studies.

Data from Korbelt R, Leitenstorfer P. Clinical estimation of lacrimal function in various bird species using a modified Schirmer tear test. *Isr J Vet Med* 1996;51:171–5; Williams DL, Villavincencio CM, Wilson S. Chronic ocular lesions in tawny owls (*Strix aluco*) injured by road traffic. *Vet Rec* 2006;159:148–53; Harris MC, Schorling JJ, Herring IP, et al. Ophthalmic examination findings in a colony of Screech owls (*Megascops asio*). *Vet Ophthalmol* 2008;11(3):186–92.

of intraocular pressures in raptors with uveitis and glaucoma. Primary and secondary causes of glaucoma have been reported in raptors, with 10 of 13 cases occurring in great horned owls (*Bubo virginianus*).^{118,126} Reference ranges have been established for various birds of prey including red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*Buteo swainsoni*), golden eagles (*Aquila chrysaetos*), bald eagles (*Haliaeetus leucocephalus*), tawny owls (*Strix aluco*), Eurasian eagle owls (*Bubo bubo*), and great horned owls (*Bubo virginianus*).^{127,128} Reference values for intraocular pressures in raptors are listed in **Table 6**. Many clinicians do not frequently perform indirect ophthalmic evaluation; however, it should be strongly considered as it provides visualization of a wide field of view of the retina.

The causes of ophthalmic disease are as numerous for raptors as they are for domestic species. Despite this fact, traumatic events dominate the reports in the literature. Additional reports including degenerative, nutritional, neoplastic, infectious, inflammatory, metabolic, and toxic causes of ocular disease can also be found.^{130–133} The most common disease condition seen in geriatric raptors, second only to osteoarthritis, is the development of cataracts. Cataracts can develop in birds due to traumatic, developmental, genetic, toxic, or inflammatory lesions.^{134–136} Cataracts may be further classified as traumatic, juvenile, or senile types.¹³³ Senile cataracts are the second most frequently quoted type of cataract after those resulting from traumatic injuries.^{133,137–139} Recommended treatment may be palliative, medical, or surgical. Surgical therapy may be chosen due to the inability to apprehend food, inability to mate, continued self trauma, or other factors that may affect quality of life. Surgical treatment of cataracts has been accomplished by needle aspiration, extracapsular extraction, and ultrasonic phacoemulsification.^{129,134,138} Indication for cataract surgery is based on evaluation of the patient for current or preexisting medical conditions, as well as the possibility of acceptable postoperative vision. Assistance by a board certified ophthalmologist is invaluable when formulating a plan before a final determination is made. Although the body of knowledge has increased on ophthalmic conditions in raptors over the last 20 years, additional work is still needed regarding ophthalmic conditions in geriatric raptors.

Neurologic Diseases

Most neurologic disease conditions seen in raptors are related to trauma, toxin ingestion and exposure, or infectious origins, such as West Nile virus. Neoplastic, cardiovascular, metabolic, and idiopathic diseases may also result in clinical signs associated with neurologic disease. In geriatric raptors, neurologic conditions are usually the result of neoplastic, cardiovascular, metabolic, and idiopathic diseases and may result in senility, cerebral ischemic events, seizures, and various other neurologic abnormalities.

Senility is occasionally seen in geriatric raptors under the care of falconers or zoologic institutions. Signs of cognitive dysfunction indicating senility include changes in the sleep/wake cycle, inattention to food, inattention to environment, inability to recognize familiar people or objects, or inability to perform learned behaviors. In other species, neurotransmitters change with age, and this likely also occurs in birds.¹⁴⁰ As animals age, acetylcholinesterase and monoamine oxidase b levels increase as choline aminotransferase and serotonin levels decrease and lipofuscin accumulates in the cytoplasm of the neurons. In addition, the brain becomes chronically hypoxic with age due to arteriolar fibrosis and endothelial proliferation. Although these changes have been recognized in other species, to the author's knowledge they have not been evaluated in relation to raptors and other avian species. Ultimately, senility is ruled out by exclusion of other differentials that can be definitively

Table 6
Intraocular pressures in birds of prey

Common Name	Scientific Name	No. of Birds	Method of Tonometry Measurement	Normal/Abnormal	IOP mm Hg (\pm SD)	References
Barred owl	<i>Strix varia</i>	1	Applanation	Right: anterior lens luxation Left: normal	R: 18 L: 18	129
Great horned owl	<i>Bubo virginianus</i>	1	Applanation	Right: corneal perforation and iris prolapse Left: luxated lens, corneal edema, corneal neovascularization	Unable to acquire L: 34	130
Great horned owl	<i>Bubo virginianus</i>	Unknown	Applanation	Normal	10–14	130
Great horned owl	<i>Bubo virginianus</i>	1	Applanation	Right/Left: blind, episcleral congestion, mydriasis, exposure keratitis, abnormal iridocorneal angles, and curled/atrophied pectinate ligament	R: 42.4 (\pm 5.6) L: 26.4 (\pm 1.8)	126
Great horned owl	<i>Bubo virginianus</i>	3	Applanation	Normal	7.1 (5.2–7.8)	126

Tawny owl	<i>Strix aluco</i>	26	Applanation	See below	See below	124
		Unknown	Applanation	Normal	15.6 (± 3.4)	124
		Unknown	Applanation	With adnexal lesions	14.2 (± 3.6)	124
		Unknown	Applanation	With corneal lesions	18.2 (± 5.4)	124
		Unknown	Applanation	Anterior segment inflammatory pathology	7.4 (± 4.6)	124
		Unknown	Applanation	Iridio- or cyclodialysis	35.4 (± 12.2)	124
		Unknown	Applanation	Lens pathology alone	12.2 (± 3.8)	124
		Unknown	Applanation	Posterior segment pathology alone	13.6 (± 4.8)	124
Eurasian Eagle owl	<i>Bubo bubo</i>	10	Applanation	Normal	9.35 (± 1.81)	128
		10	Rebound	Normal	10.45 (± 1.64)	128
Red-tailed hawk	<i>Buteo jamaicensis</i>	10	Applanation	Normal	20.6 (± 3.4)	127
Swainson's hawk	<i>Buteo swainsoni</i>	6	Applanation	Normal	20.8 (± 2.3)	127
Golden eagle	<i>Aquila chrysaetos</i>	7	Applanation	Normal	21.5 (± 3.0)	127
Bald eagle	<i>Haliaeetus leucocephalus</i>	3	Applanation	Normal	20.6 (± 2.0)	127
Great horned owl	<i>Bubo virginianus</i>	6	Applanation	Normal	10.8 (± 3.6)	127

diagnosed. Record keeping specifically related to the behavioral condition of the bird is the most critical aspect to formulating a differential diagnosis of senility in raptors. Medical therapies are available for humans and canines for the treatment of senility, but these medications have not been evaluated for use in birds.

Seizures, tremors, and other cerebral/cerebellar conditions in geriatric raptors can be caused by neoplastic, metabolic (hepatic encephalopathy), cardiovascular, and idiopathic conditions. As stated earlier, toxic exposure and trauma may result in the majority of neurologic conditions, yet in geriatric birds, age-related changes should result in expansion of the clinicians' differential list. Neoplastic, hepatic, and cardiovascular diseases discussed earlier could each contribute to a patient's neurologic symptoms. Defining whether the neurologic disease is primary or secondary to another condition is crucial to implementing appropriate therapy for the patient. A 26-year-old golden eagle (*Aquila chrysaetos*) with opisthotonos, inappetence, incoordination, and stargazing was evaluated by the author. Only after exclusion of infectious, inflammatory, metabolic, toxic, and traumatic causes, and evaluation by computed tomography of the brain with contrast media, was a definitive diagnosis of a cerebral ischemic event able to be confirmed (Figs. 10–12). Other reports of neurologic conditions in raptors have been classified as idiopathic until further work is performed to delineate a definitive diagnosis. Avian vacuolar myelinopathy is a condition with an unknown etiology that has affected bald eagles, a great horned owl, and several species of waterfowl, and has been recognized periodically in North America.¹⁴¹ Although a neurotoxin is suspected, further investigation is needed. Diagnosis and evaluation of neurologic conditions in geriatric birds is still in its early stages, and extensive work is needed to thoroughly understand the impact of these conditions on the health of raptors under human care.

Reproductive Diseases

Reproductive disease in aged raptors has not received adequate attention in the literature compared with other subjects. Although reproductive diseases are covered in various texts, the effect of age and age-related conditions is poorly understood. The reproductive lifespan of most raptors has not been established, nor have all the factors that influence it been identified. Conditions resulting in secondary effects on mating may also influence fecundity. Osteoarthritis may affect reproductive abilities for both the male and female. The male may be unable to mount the female, and dystocia



Fig. 10. Golden eagle (*Aquila chrysaetos*) with severe torticollis that was suspected to be due to a cerebral ischemic event. (Courtesy of Tim Tristan, DVM.)



Fig. 11. Full recovery was achieved in the Golden eagle in [Fig. 10](#) after approximately a month of intense supportive care. (Courtesy of Tim Tristan, DVM.)

may become a concern for the female during the egg-laying process. Abnormal plumage near and around the cloaca may also hinder the ability for individuals to copulate. Neoplastic diseases affecting abdominal organs, the reproductive tract, and the cloacal region can also cause problems in reproduction.

Decrease in the reproductive potential of the geriatric male or female can also be primarily associated with the reproductive system. Low sperm counts, decreased sperm volume, decrease sperm motility, and poor sperm morphology are seen in geriatric animals of other species, and need to be taken into consideration with raptors. Decreased receptivity may be observed, and can be a consequence of decreased



Fig. 12. Many times the history can aid the clinician in determining the diagnosis. This barn owl (*Tyto alba*) with torticollis was due to head trauma from a motor vehicle. (Courtesy of Tim Tristan, DVM.)

libido resulting from a drop in hormone production over time for both males and females. Egg production also declines in females partly due to the extensive energy expenditure on the individual. Despite the possible causes of reproductive failure, the effect of age and age-related conditions needs to be more comprehensively examined.

Miscellaneous Conditions

Various other conditions should be considered when caring for geriatric raptors. Age-related changes in other species may result in changes in the immune, integumentary, and respiratory systems. In addition, special attention should be paid to anesthesia and clinical pathologic interpretation.

The immune system and respiratory system each exhibit age-related changes in other species, including humans and canines. A decline in the immune function is seen with many species and can result in increased susceptibility to infectious disease conditions. Alterations in hematology and the biochemical parameters have not been evaluated in geriatric raptors, but may prove critical to a complete understanding of the patient. Age-related decreases in chest wall compliance, pulmonary compliance, and pulmonary elastic fiber properties are seen in dogs with increased age, and this can be appreciated on physical examination and noted by subtle clinical signs of respiratory disease.¹⁴² Similar anatomic and physiologic changes in the respiratory system of geriatric raptors have not been observed to date, and further investigation is warranted. Poor feather quality, including frayed, dull feathers, may be seen in geriatric raptors. Decreased preening due to osteoarthritis or other conditions may affect the health and visual appearance of feathers over time. Other factors including nutrition, infectious agents, and neoplastic disease may also contribute to poor feather quality.

Obesity is frequently seen in elderly raptors in captivity due to decreased activity and overfeeding. Special attention should be made to closely monitor raptor weights to ensure that they remain within their target parameters. Obesity may lead to or exacerbate medical conditions such as osteoarthritis and cardiovascular disease, and eventually may result in decreased life expectancy.

Finally, anesthetic considerations should be accounted for as in other geriatric animals. Complete evaluation of the patient, including physical examination, hematology, biochemistry, and radiographs should be performed to provide baseline data. A thorough workup allows for evaluation of the patient for any underlying or undiagnosed disease conditions that may complicate an anesthetic procedure. Although many clinicians may sedate patients before performing diagnostics, the benefits and risks should be considered before anesthetizing a geriatric bird.

SUMMARY

The limited information available on geriatric raptors emphasizes the extensive effort that is still needed to expand the knowledge and understanding of these specialized patients. Although raptors have been intimately involved with humans for centuries, the medical aspects have lagged behind until recently. Rehabilitation centers have become a major component, allowing a better understanding of medical conditions in raptors, with increased involvement from local veterinarians. Falconers' use of veterinary services has enhanced the care and medical management through a team approach by both disciplines. The improvement in care, husbandry, and medical management at zoologic institutions has and will continue to be a vital component to further understanding of raptors. Ultimately, contributions made by

all the groups discussed here will be imperative to the future of geriatric raptor medicine.

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